[TRANSLATION]

AMENDMENT UNDER ARTICLE 34 PCT

FILED JANUARY 16, 2004

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laser are disclosed, and the operation of the means will be described.

[0036] In order to accomplish the above object, the present invention provides a light source device having a light source element from which output light is emitted to outside via a multiple scattering optical system, wherein the multiple scattering optical system includes at least a first region that is located adjacent to the light source element, and a second region that abuts on the first region and reaches the outside, of the first and second regions, at least the first region contains scatterers, and a density of the scatterers in the first region is higher than a density of scatterers in the second region, and the light source element has an optical waveguide structure. The second region may have a lens portion. Alternatively, the second region may serve as a magnifier for at least a principal portion of a secondary planar light source formed at an interface between the first region and the second region.

[0037] According to the light source device of the above-mentioned construction, by generating mainly in the first region the multiple scattering that sufficiently reduces the spatial coherency of the output light from the light source element and controlling the angular

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distribution characteristic of the radiant intensity mainly by the magnifier of the second region, the optimization of

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occurs during the operation of the light source device, it is needless to say that similar operation is effected on an attempt to use the light source device after the damage has once occurred.

In one embodiment, assuming that a transport mean free path of the scatterers is l_{AVE} and a dimension in the optical axis direction of the first region is L, then a transport optical depth L/l_{AVE} is approximately 1 to 100.

[0095] Moreover, an optical communication module of this invention is characterized in that the aforementioned light source device is used as a the transmission means.

[0096] According to the optical communication module, by employing the light source device as the transmission means and further employing, for example, an Si photodiode as a light reception means, there can be provided an optical communication module that satisfies the Class 1 eye safety and concurrently is most inexpensive and excellent in electric optical characteristics for wireless optical communications. Moreover, particularly in an optical communication module, the first region of the multiple scattering optical system is formed as a minute region located adjacent to the light source element (semiconductor laser). Therefore, even when the device is integrated with or formed into an integrated module with a photodiode, the reception system does not suffer the disadvantages of

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sensitivity degradation and so on. Therefore, by forming an optical communication module by a combination of an inexpensive Si photodiode with the light source device of this invention, there can be provided an optical

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 (2)

WHAT IS CLAIMED IS:

1.(Amended) A light source device having a light source element from which output light is emitted to outside via a multiple scattering optical system, wherein

the multiple scattering optical system includes at least a first region that is located adjacent to the light source element, and a second region that abuts on the first region and reaches the outside,

of the first and second regions, at least the first region contains scatterers, and a density of the scatterers in the first region is higher than a density of scatterers in the second region, and

the light source element has an optical waveguide structure.

2.(Amended) The light source device as claimed in claim 1, wherein

the device comprises a recess portion having a wall surface and a bottom surface that define the first region, wherein a metal layer is formed on at least part of the wall surface and/or of the bottom surface, and the light source element is directly or indirectly fixed to the bottom surface, and

a surface of the metal layer formed on the at least part of the wall surface and/or of the bottom surface

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of the recess portion serves as a reflective surface to scattered light of the output light from the light source element.

3. (Amended) The light source device as claimed in claim 2, wherein

the metal layer on the at least part of the wall surface and/or of the bottom surface of the recess portion is continuously formed so that substances other than the metal are not exposed in a principal portion positioned within reach of the scattered light spatially distributed in the first region.

4. (Amended) The light source device as claimed in claim 2, wherein

the surface of the metal layer formed on at least part of the wall surface of the recess portion serves as a reflective surface that changes an optical axis direction of an outgoing beam of the light source element toward an interface between the first and second regions, and

the size parameter q of the first region falls within a range of approximately 1 to 15.

5. (Amended) The light source device as claimed in claim 2, wherein

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the surface of the metal layer formed on at least part of the wall surface of the recess portion serves as a reflective surface that changes an optical axis direction of an outgoing beam of the light source element a plurality of times, and

the size parameter q of the first region falls within a range of approximately 10 to 50.

6. (Amended) The light source device as claimed in claim 5, wherein

an opening of the recess portion has a diameter larger than that of the bottom surface, and

assuming that a ratio of a depth to the diameter of the bottom surface of the recess portion is given as an aspect ratio, r, and an angle made between a normal line of the wall surface of the recess portion and the optical axis of the outgoing beam of the light source element is θ [deg], then a condition expressed by:

$$\max\{2r, 3\} \le \theta \le 20r$$

is satisfied.

7. (Amended) The light source device as claimed in claim 5, wherein

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at least part of the wall surface of the recess portion forms a cylinder whose top and bottom have approximately same sectional configurations, and

assuming that a ratio of a depth to a diameter of the cylinder of the recess portion is given as an aspect ratio, r, and an angle made between a normal line of the wall surface of the recess portion and the optical axis of the outgoing beam of the light source element is θ [deg], then a condition expressed by:

$$\max\{\mathrm{atan}(r/5), 3\} \le \theta \le \mathrm{atan}(r/2)$$

is satisfied.

8. (Amended) The light source device as claimed in claim 1, wherein

the second region has a lens portion.

9. (Amended) The light source device as claimed in claim 8, wherein

the lens portion serves as a magnifier for at least a principal portion of a secondary planar light source formed at an interface between the first region and the second region.

10. (Amended) The light source device as claimed in claim 1, wherein,

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assuming that a size parameter q, which represents a relation between a particle size mode Ds of the scatterers and a center wavelength λ in a base material of the first region of the light source element, is expressed by:

$$q = (2\pi/\lambda)\cdot(Ds/2),$$

then the particle size mode Ds of the scatterers is within a range that allows the size parameter q to fall within a range of approximately 1 - 50, and at least the first region includes a portion where the scatterers are dispersed at a high density so that an average nearest neighbor distance of the scatterers becomes equal to or smaller than twenty times the particle size mode Ds of the scatterers.

11. (Amended) The light source device as claimed in claim 1, wherein

the first region employs a gel-like or rubber-like material as the base material.

12. (Amended) The light source device as claimed in claim 1, wherein

the light source element is a semiconductor laser.

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13. The light source device as claimed in claim 12, wherein

the semiconductor laser has an active layer including an InGaAs layer on a GaAs substrate and an emission wavelength within a range of from 880 nm to 920 nm inclusive.

14. The light source device as claimed in claim 13, wherein

the semiconductor laser has the active layer including the InGaAs layer on the GaAs substrate and includes at least one of a ternary layer or a quaternary layer which are expressed by $In_XGa_{1-X}As_YP_{1-Y}$ ($0 \leq X < 1$, $0 < Y < 1$).

15. (Amended) The light source device as claimed in claim 12, wherein

the semiconductor laser has spatial fluctuations in at least one of its composition or its layer thickness.

16. The light source device as claimed in claim 14, wherein

the semiconductor laser has the active layer including the InGaAs layer on the GaAs substrate and includes at least one of a ternary layer or a quaternary

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layer expressed by $In_XGa_{1-X}As_YP_{1-Y}$ ($0 \leq X < 1$, $0 < Y < 1$) which has spatial fluctuations in its composition.

17. (Amended) The light source device as claimed in claim 1, wherein

at least part of a wire connected directly or indirectly to the semiconductor laser exists inside the second region.

18. (Amended) An optical communication module employing the light source device claimed in claim 1 as a transmission means.

19. (Added) The light source device as claimed in claim 1, wherein

assuming that a transport mean free path of the scatterers is l_{AVE} and a dimension in the optical axis direction of the first region is L, then a transport optical depth L/l_{AVE} is approximately 1 to 100.

Fig.5A

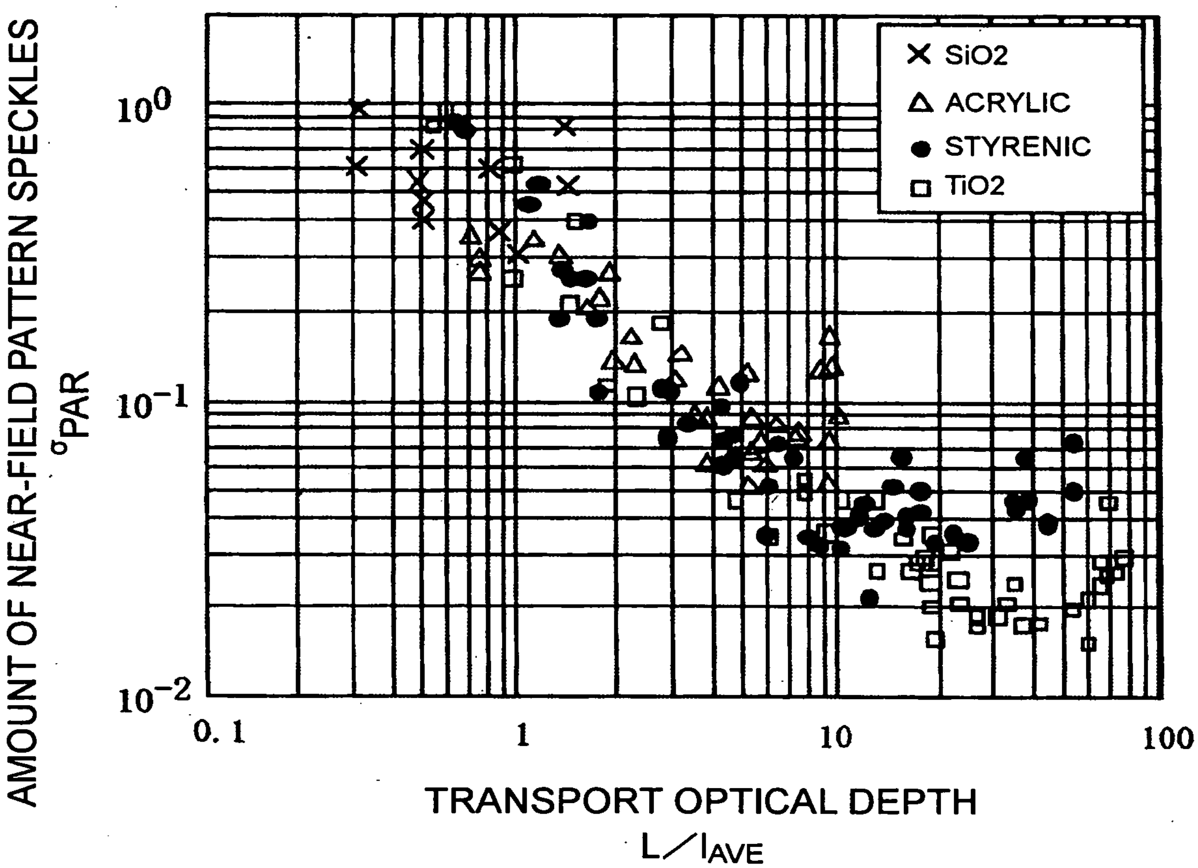
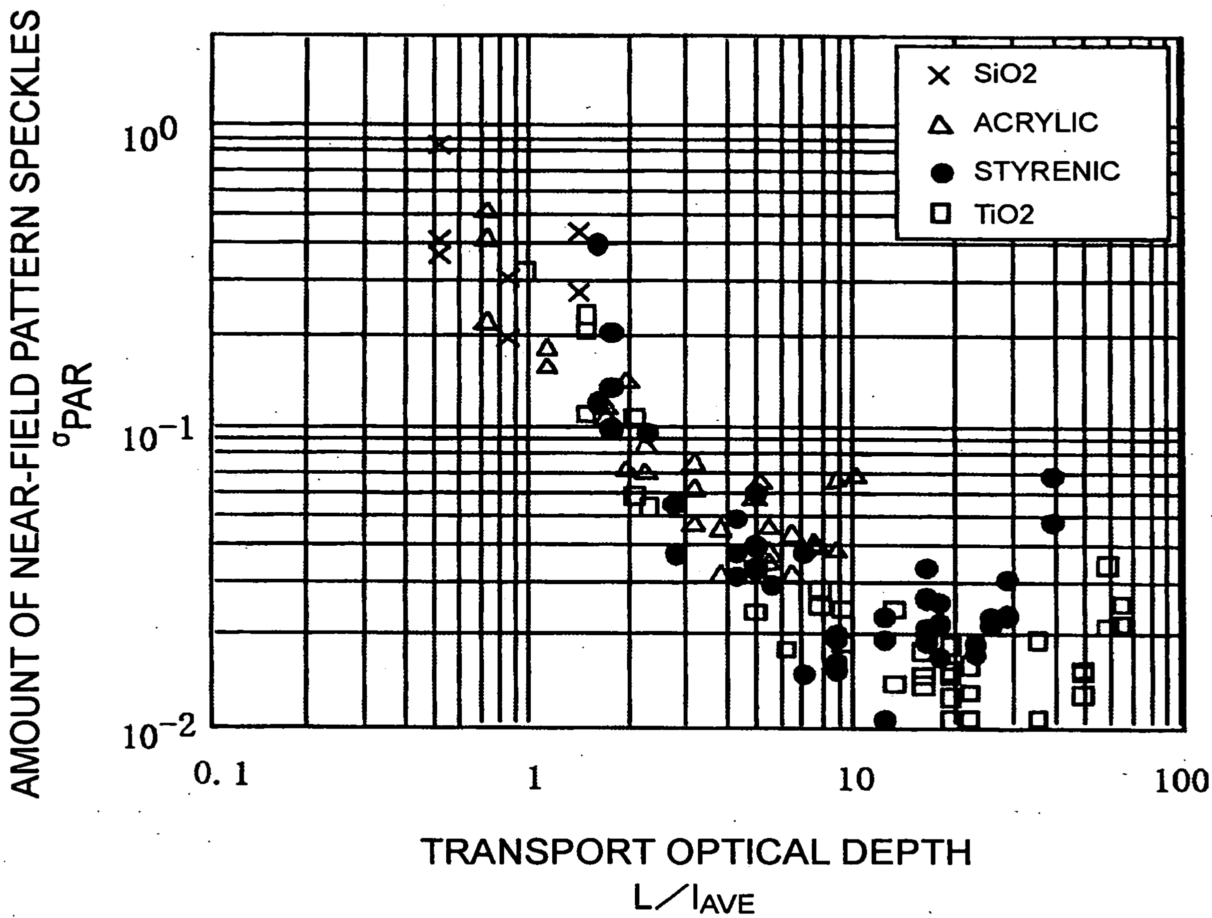

SiO2
ACRYLIC
STYRENIC
TiO2
10^0
10^{-1}
10^{-2}
0. 1
1
10
100
AMOUNT OF NEAR-FIELD PATTERN SPECKLES
σ_{PAR}
TRANSPORT OPTICAL DEPTH
L/l_{AVE}

Fig. 8



AMOUNT OF NEAR-FIELD PATTERN SPECKLES
σPAR
10^0
10^-1
10^-2
0. 1
1
10
100
SiO2
ACRYLIC
STYRENIC
TiO2
TRANSPORT OPTICAL DEPTH
L／lAVE